DOCUMENT RESUME

ED 182 589 CE 024 274

AUTHOR Groseclose, Richard
TITLE Nuclear Technology. Course 29: Civil/Structural Inspection. Module 29-4, Concrete Preparation, Production, Placement and Finishing.
INSTITUTION General Physics Corp., Columbia, Md.
SPONS AGENCY Office of Education (DHEW), Washington, D.C.
PUB DATE 79
CONTRACT 300-77-0340
NOTE 47p.; Small, light type in figures will not reproduce well; For related documents see CE 024 245-298

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Construction Management; Course Content; Energy; Inspection; Learning Activities; Learning Modules; *Nuclear Physics; Postsecondary Education; *Quality Control; Teaching Guides; *Technical Education
IDENTIFIERS Cement; Cement Construction; Nuclear Energy; Nuclear Energy Occupations; *Nuclear Power Plant Technicians; *Nuclear Technology

ABSTRACT

This fourth in a series of six modules for a course titled Civil/Structural Inspection describes concrete preparation, production, placement, and finishing. The module follows a typical format that includes the following sections: (1) introduction, (2) module prerequisites, (3) objectives, (4) notes to instructor/student, (5) subject matter, (6) materials needed, (7) procedures, (8) data table, (9) reference materials, (10) test. (The course is one of fifteen technical courses for the second year of a two-year postsecondary curriculum in Nuclear Quality Assurance/Quality Control Technology.) (LRA)

**********
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
**********

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

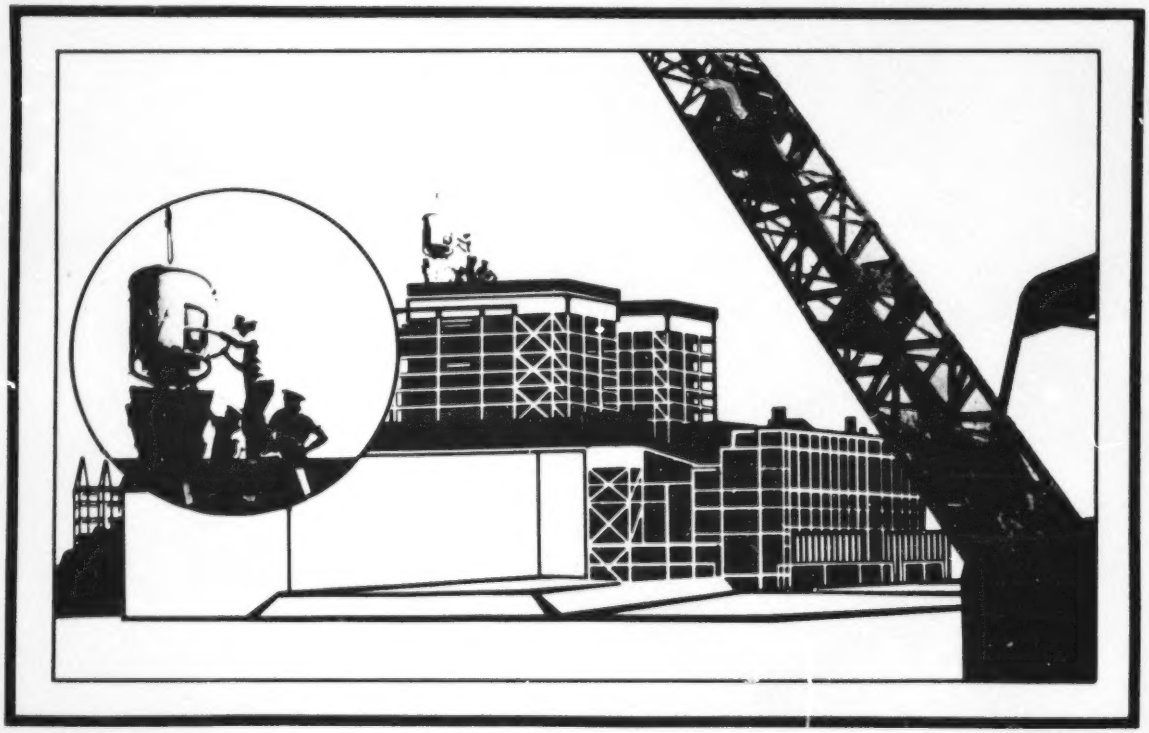
THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY.

ED182589

# NUCLEAR TECHNOLOGY

## COURSE 29 CIVIL/STRUCTURAL INSPECTION

### MODULE 29-4 Concrete Preparation, Production, Placement and Finishing



CE 024 274

GENERAL PHYSICS CORPORATION
Columbia , Maryland

# COURSE MODULES

COURSE 29 CIVIL/STRUCTURAL INSPECTION

| | |
|---|---|
| Module 29-1 | Inspection of Construction Operations |
| Module 29-2 | Structural Steel Materials, Installation, and Inspection |
| Module 29-3 | Concrete Materials |
| Module 29-4 | Concrete Preparation, Production, Placement and Finishing |
| Module 29-5 | Concrete Testing and Inspection |
| Module 29-6 | Prestressed Concrete Materials, Fabrication, and Inspection |

The material in this module was developed by General Physics Corporation under a contract with the United States Department of Health, Education and Welfare, Office of Education, Contract Number 300770340. Contractors undertaking such projects are encouraged to express freely their professional judgement in the conduct of the project. Therefore, points of view or opinions stated do not necessarily represent official Office of Education position or policy.

This module was prepared for General Physics Corporation by Richard Groseclose, General Physics Corporation.

GENERAL PHYSICS CORPORATION

1979

# INTRODUCTION

Vast quantities of concrete are required on construction projects such as the typical nuclear power plant. To meet the design requirements, the concrete must have the required strength, and be homogeneous, water-tight and resistant to weather. These properties can only be obtained through quality workmanship and adherence to the applicable codes, standards and specifications.

This module introduces some of the organizations which develop codes and standards for the construction industry, and lists the commonly used standards for structural concrete work.

Various types of concrete and their uses are described, along with the use of additives and special materials. Special techniques employed in hot weather and cold weather concreting operations are presented.

Equipment used in concrete production, such as for batching, mixing and transporting, is described, and various techniques of placement, consolidation and finishing are discussed.

Grouting operations are defined and described, and the use of construction joints and various finishing methods explained.

The QA/QC technician could easily be involved in any or all of these construction activities. Codes and specifications are used in generating purchase orders for materials, and in establishing acceptance criteria for receiving the materials. Standards and accepted-practice guides are used in developing work procedures, inspection procedures, and inspection check lists.

In functioning as a concrete inspector, the QA/QC technician would have to be familiar with all aspects of concrete production, placement and finishing methods and practices, and the methods of documenting and reporting the

activities inspected and attendant test results. Various types of records are discussed, and typical concrete pre-placement, placement, and post-placement record forms are illustrated.

## MODULE PREREQUISITES

The student/trainee should complete Modules 29-1 and 29-3 before proceeding with this module.

## OBJECTIVES

Upon completion of this module, the student trainee should be able to perform the following:

1. Given a list of construction activities related to concreting operations, identify appropriate standards or recommended practice guides.
2. Complete a set of written exercises which demonstrate a knowledge of concrete production practices.
3. Given a set of written questions about concrete production equipment, select the correct answers.
4. Answer correctly a set of questions about various aspects of concrete placement and consolidation.
5. Given descriptions of typical grouting operations, answer pertinent written questions and calculate mix proportions.
6. Demonstrate a knowledge about construction joints, and concrete finishing and cleanup operations by answering correctly a set of written questions.

# SUBJECT MATTER

## CODES AND STANDARDS

ASTM

The ASTM, American Society for Testing and Materials, is a scientific and technical organization whose charter is to develop standards on characteristics and performance of materials, products, systems and services; and the promotion of related knowledge. It is the largest organization of its type in the world, and is composed of representatives from all fields, most of whom are recognized as technical experts in their fields.

Part 10 of the ASTM Annual Book of Standards is titled "Concrete and Mineral Aggregates". Part 10 includes many standards relating to concrete, cement, aggregates, curing materials, admixtures, and a manual of concrete testing. The following standards from Part 10 are used routinely for the production and control of concrete for projects such as nuclear power plants:

| | |
|---|---|
| ASTM C33 | Specification for Concrete Aggregates |
| ASTM C94 | Specification for Ready-Mixed Concrete |
| ASTM C125 | Definition of Terms Relating to Concrete and Concrete Aggregates |
| ASTM C143 | Test for Slump of Portland Cement Concrete |
| ASTM C150 | Specification for Portland Cement |
| ASTM C173 | Test for Air Content of Freshly Mixed Concrete by the Volumetric Method |

ACI

The ACI, American Concrete Institute, is a technical organization composed of members who are technical experts and represent concrete users and concrete producers.

The following standards are published individually as well as in Part 1 of the ACI Mnaual of Concrete Practice, and are frequently imposed for concreting operations in the construction of nuclear power plants:

| | |
|---|---|
| ACI 211.1 | (ANSI A167.1) Recommended Practice for Selecting Proportions for Normal Weight Concrete |
| ACI 212.1 | (Title No. 68-56) Guide for Use of Admixtures in Concrete |
| ACI 212.33 | (Title No. 60-64) Admixtures for Concrete |
| ACI 214.65 | (ANSI 146.1) Recommended Practice for Evaluation of Compression Test Result of Field Concrete |
| ACI 221.1 | (Title No. 58-24) Selection and Use of Aggregates for Concrete |
| ACI 304.73 | Recommended Practice for Measuring, Mixing, Transporting, and Placing Concrete |
| ACI 304 | (Title No. 68-33) Placing Concrete by Pumping Methods |
| ACI 305.72 | Recommended Practice for Hot Weather Concreting |
| ACI 306.66 | (ANSI A144.1) Recommended Practice for Cold Weather Concreting |
| ACI 308.71 | Recommended Practice for Curing Concrete |
| ACI 309.72 | Recommended Practice for Consolidation of Concrete |
| ACI 311.64 | Recommended Practice for Concrete Inspection |
| ACI 347.68 | (ANSI A145.1) Recommended Practice for Concrete Formwork |

NRMCA

The NRMCA, National Ready Mixed Concrete Association, is an organization represented by concrete producers, which develops and publishes guides relative to the production, use, quality and acceptability of ready-mixed concrete.

Some of their frequently used publications are as follows:

Ready-Mixed Concrete Specifications and Their Administration
Standards for Operation of Truck Mixers and Agitators of the National Ready-Mixed Concrete Association
Cold Weather Ready-Mixed Concrete
Cooling Ready-Mixed Concrete
Sampling and Testing Ready-Mixed Concrete

CRSI

The CRSI, Concrete Reinforcing Steel Institute, is comprised of fabrication and producers of reinforcing steel. One of their most useful publications is Placing Reinforcing Bars which presents the best-accepted current practices in placing reinforcing bars, bar supports and welded wire fabric.

## CONCRETE PRODUCTION

Concrete is formulated and batched differently for different applications. Concrete known as normal weight concrete is the general type most used in plant construction work, and usually has a weight denstiy of from 130 to 160 pounds per cubic foot. It is mixed with aggregates of normal density, as distinguished from lightweight or high

density aggregates. Most normal weight concrete is proportioned to produce compressive strengths form 2,500 to 5,000 pounds per square foot, and may be formulated with admixtures to produce a variety of special characteristics, such as accelerated or retarded set, improved workability, increased strength, or reduction in mixing water. It is used for many applications, including foundations, slabs, walls and columns.

Structural lightweight concrete is concrete that, (1) is made with lightweight aggregates, (2) has a compressive strength in excess of 2,500 pounds per square inch when tested at 28 days, and (3) has a weight density (air dry weight) not in excess of 115 pounds per cubic foot. Structural lightweight concrete is used for two main purposes: (1) to reduce the weight of the structure, thereby reducing the required size of structural supporting members, or (2) to use as structural and/or thermal insulating or fill material.

When lightweight concrete is used for weight reduction properties alone, the aggregates listed in ASTM specification C 330, classed as Group II materials are to be used. These materials include blast furnace slag, shale, slate, fly ash, scoria and pumice. These materials typically produce concrete with a weight density of from 90 to 115 pounds per cubic foot, which is used for walls and slab construction.

When lightweight concrete is selected for thermal insulating properties, ASTM specification Group I materials, perlite or vermiculite, are used, or a combination of Group II and Group I materials are used. Group I materials can be used to produce insulating concrete with a weight density of from about 20 to 90 pounds per cubic foot, which may be used for floor fill, fire walls, fire protection, and roof construction. The range of unit weights normally obtained in concrete made from lightweight aggregates is shown in Figure 29-4-1.

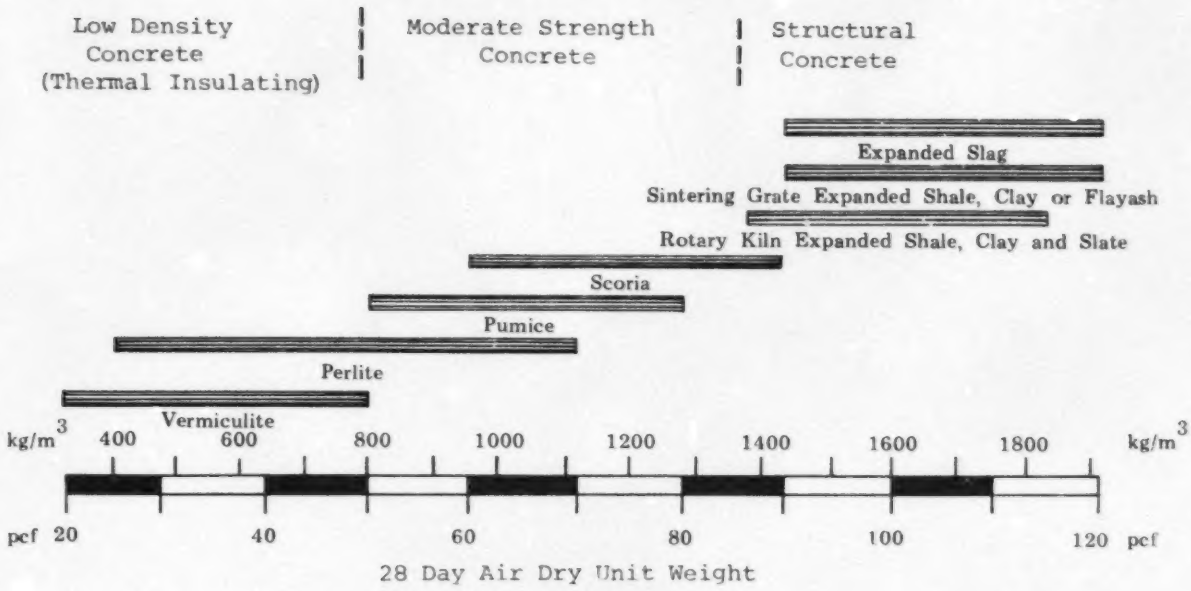

Low Density Concrete (Thermal Insulating)
Moderate Strength Concrete
Structural Concrete
Expanded Slag
Sintering Grate Expanded Shale, Clay or Flayash
Rotary Kiln Expanded Shale, Clay and Slate
Scoria
Pumice
Perlite
Vermiculite
kg/m3 400 600 800 1000 1200 1400 1600 1800 kg/m3
pcf 20 40 60 80 100 120 pcf
28 Day Air Dry Unit Weight

Figure 29-4-1. Lightweight Aggregate Concretes: Unit Weight and Uses Classification

Heavyweight aggregate concrete is high density concrete used primarily for radiation shielding. Aggregates such as bariet, magnetite, hematite and serpentine sometimes are used, and generally selected by the physical properties required. In cases where the weight density of the concrete is required to exceed 300 pounds per cubic foot, steel punchings or lead balls and lead shot may be used. Boron additions also may be used to increase the radiation absorption properties of concrete, but set-time and early strength development may be adversely affected.

Weather Conditions

Weather is an important factor in concrete production and placement. Different procedures and techniques are used for hot weather and for cold weather concreting.

As it affects concrete, hot weather is defined as any combination of high air temperature, low relative humidity, and wind velocity tending to impair the quality of fresh or hardened concrete. The effects of hot weather are most critical during periods of rising temperature, falling relative humidity, or both. The adverse effects are more serious on a dry, windy day than a calm, humid day at identical air temperatures. Some of the undesirable hot weather effects are:

- Rapid evaporation of mixing water
- Difficulties with normal handling, finishing and curing
- Difficulty in controlling entrained air
- Accelerated set
- Increased tendency to crack or craze
- Reduced strength
- Reduced bond of concrete to reinforcing steel
- Possible "cold" joints

## PRODUCTION EQUIPMENT

The selection of a concrete batch plant is usually based on, (1) the size of the job, (2) the required production rate, and (3) the required standards of accuracy or batching standards. A plant consists of compartmented bins for storing cement and aggregate materials separately, scales for weighing the materials when they are batched, and storage and dispensing equipment for mixing water and for admixtures.

For jobs requiring batching rates up to about 25 cubic yards per hour, manual batch plants frequently are used. For larger jobs, however, semi-automatic or automatic batching equipment is used. With the more sophistocated equipment, devices such as automatic mix selectors, aggregate moisture meters and compensators, and recorders are used.

Regardless of the type of plant or equipment, the accurate measurement of total mixing water (added water, mixer wash water, ice, aggregate free moisture, etc.) is of paramount importance. All equipment for water measurement should be designed for easy calibration so that accuracy of measurement can be quickly verified.

An optimum temperature for concrete at time of placement is about 60°F; this usually cannot be attained in hot weather. A maximum of 90°F, however, is recommended by the ACI as an upper limit.

To minimize the temperature of the concrete, the ingredients should be kept as cool as possible. The temperature of the mixing water has the greatest effect of the constituents due to its higher specific heat, and, when used cold, will effect a moderate reduction in concrete placing temperatures. The use of ice as part of the mixing water is highly effective in reducing the temperature of the mix. It may be shaved or crushed and placed directly into the mixer as part or all of the required mixing water. Some additional cooling of the aggregates may be obtained from evaporation by keeping them moist prior to use. Retarders which reduce the rate of hardening and reduce the water requirements of the concrete may also be used to offset the increased water demand resulting from hot weather.

Special precautions and procedures are also required in cold weather to insure that adequate strength is attained before the concrete has an opportunity to freeze or is

exposed to temperatures low enough to impair the strength development. At any time that frost may occur, or the mean daily temperature is below 40°F, cold weather protection is necessary. To preclude freezing until adequate protection can be established, the ACI recommends that the temperature of concrete as placed should be above the following values:

Very thin sections (approximate maximum size rock: 3/4"): 55°F

Thin sections (approximate maximum size rock: 1-½"): 50°F

Moderately massive sections (approximate maximum size rock: 3"): 45°F

Massive sections (approximate maximum size rock: 6"): 40°F

In areas where temperatures do not commonly fall below freezing, it is sufficient to heat the mixing water alone to achieve these concrete temperatures. In colder climates, it may be necessary to heat the aggregates also. This may be accomplished with open or closed steam coils in the aggregate storage bins, or with heated air blown through pipes under the stockpiles. For placing concrete when the air temperature ranges from about 0° to 30°F, an optimum mixed concrete temperature is from about 60°-70°F, with a "do-not-exceed" temperature of 90°F.

Accelerating admixtures, such as calcium chloride, may also be used to accelerate the set, hasten the hardening, and develop strength earlier. These materials will not prevent freezing, however; protection will still be required during curing.

Depending on the equipment used, concrete may be mixed in a central plant (central mixed concrete) and transported to the discharge point in agitating or non-agitating truck

bodies, or mixed entirely in transit or after reaching the dishcarge point (transit mixed or truck mixed concrete) or mixed partially in a central plant and completed in transit (shrink mixed concrete).

Three types of mixers are commonly used: the drum, the vertical shaft, and the spiral blade. The drum mixer has a rotating drum with internal blades arranged to exchange the materials end-for-end, and roll, fold and spread the batch over itself. The vertical shaft mixer has revolving blades or vertical shafts operating in either a stationary pan or in a revolving pan, rotating in the opposite direction. The spiral blade mixer consists of a power driven horizcntal shaft with spiral blades, operating in a horizontal drum. Visual observation of the concrete being mixed is an important aid in maintaining a uniform mix and uniform consistency.

The ultimate strength and durability of the concrete is dependent upon accurate batching, thorough mixing, homogeneity, and water content. These factors are affected and controlled by:

1. Batcher scale accuracy and calibration
2. Water meter/control accuracy and calibration
3. Batcher/hopper discharge gates/valves precision operation
4. Mixing operations:
    a. Mixing blades clean, with no excessive wear
    b. Mixing drums clean
    c. Mixers operated at proper speed
    d. Correct mixing time observed, number of revolutions
    e. Discharge from holding drum within allowed time
    f. Maximum allowed water addition observed

## PREPARATIONS FOR CONCRETE PLACEMENT

Before concrete is placed, the forms should be thoroughly cleaned out to remove all trash and debris. In most cases, oiled forms are used, and need no further preparation. If un-treated forms are used, however, they should be sprinkled or hosed-down with water, to prevent the absorption of water by the forms from the concrete during placement and the early stages of curing.

An inspection should be conducted before placement to check proper form alignment, shoring and bracing, and proper installation of reinforcing steel and other embedded items.

If the concrete is to be placed directly on grade, rock surface or a previous concrete pour, the surface should be wet-down thoroughly with water and the excess allowed to drain off.

Finally, it should be verified that all equipment, materials and personnel are "ready to go" before concrete batching and placement begins.

### Concrete Placement

Concrete is transported to the placing site and is discharged or transferred into other equipment for delivery to the forms. This equipment includes buckets, wheelbarrows, hoppers, manual or motor propelled "buggies" (carts), chutes and drop pipes, belt conveyors, pumping equipment, and tremies. Some of these devices will be illustrated later in this section.

Buckets and choppers are normally handled with a crane, and are equipped with manual discharge gates. They may be opened or closed easily during any portion of the discharge cycle.

Wheelbarrows and buggies require smooth, rigid runways and ramps to minimize vibration and prevent separation of concrete materials in transit.

Chutes and drop pipes are used for transferring concrete from upper to lower elevations. Chutes are sloped to permit the concrete to flow continuously down the chute without segregation. Drop pipes are located in a plumb position so that the concrete will drop vertically. When using long drop pipes, it is customary to have telephone communication between the top of the pipe and the placement area.

Portable conveyors are frequently used for short lift or reach placements. These machines cantilever the discharge point beyond the undercarriage wheels and can be elevated or lowered by self-contained units.

Stationary conveyors made up of a number of belt conveyors in series applications. The feeder belts used for such long reach placements operate at high speed to minimize the time concrete is exposed to adverse weather such as wind and hot sun.

Concrete is fed to conveyors through hoppers to obtain a uniform ribbon of material along the belt. The belts are well supported to obtain smooth, non-vibrating travel to minimize segregation.

Pumped concrete is concrete that is conveyed by pressures through either rigid pipe or flexible hose and discharged directly into the placing area. Pressure is applied by piston pumps, compressed air, or squeeze pressure. Concrete mixes for pumping must be plastic and well mixed. Particular attention should be given to the mortar (cement, sand and water) and to the amounts and sizes of coarse aggregates, as material uniformity is imperative for a successful pumping operation.

As important as the way concrete is batched, mixed and transported, is the way it is discharged into handling equipment and into forms. Concrete will separate seriously unless discharged and handled properly.

When filling hoppers, buckets or buggies, the concrete should be dropped vertically into the center of the receptacle, and not allowed to strike sloping sides. If this practice is not observed, separation will result.

When dropping concrete from a conveyor or chute, a "down pipe" should be used, as shown in Figure 29-4-2, to prevent separation. The "down pipe" should be used regardless of the length of the conveyor or chute, or whether the concrete is being discharged into hoppers, buckets, cars, trucks or forms.

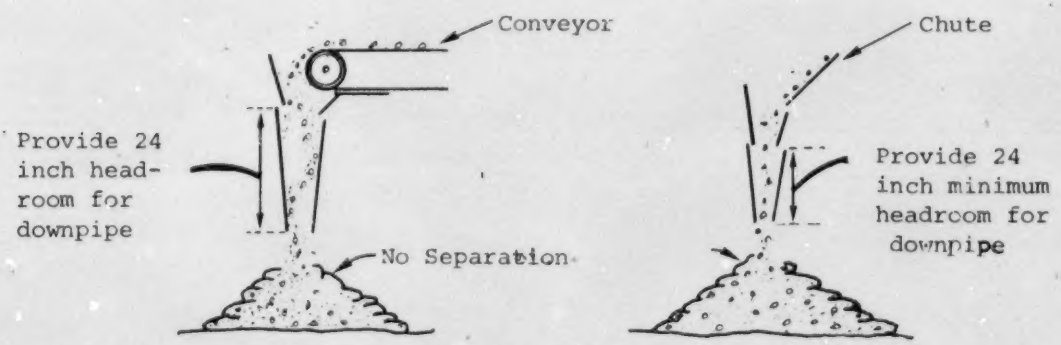



Figure 29-4-2. Discharge of Concrete From Conveyor or Chute

When concrete is transferred from one conveyor belt to another, a chute-like device as shown in Figure 29-4-3 may be used, similar in function to a down-pipe, to prevent separation.

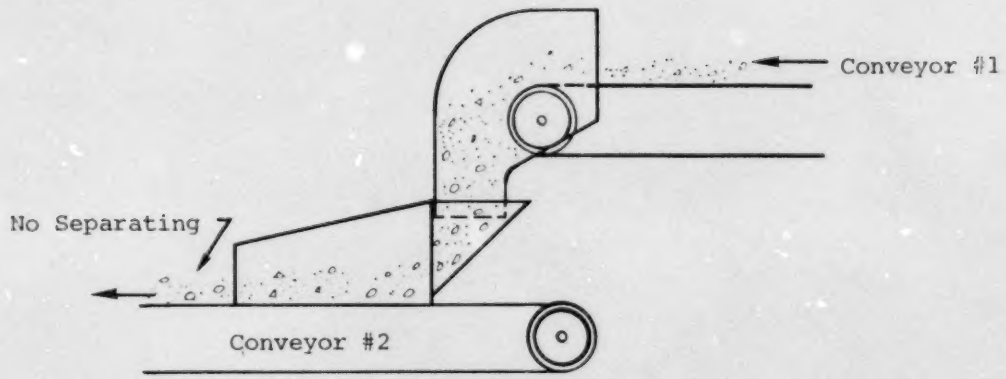



Figure 29-4-3. Transfer of Concrete, Conveyor to Conveyor

Two types of concrete pumps are shown in Figures 29-4-4 and 29-4-5, the piston type and squeeze pressure type. In the piston type, concrete is discharged into the hopper, the inlet valve opens while the outlet valve is closed, and the piston action draws concrete into the cylinder. The outlet valve then opens, the inlet valve closes, and the piston pushes the concrete from the cylinder into the delivery pipe.

In the squeeze pressure pump, the concrete is deposited in the collecting hopper, where rotating blades push it toward and into the flexible rubber pumping tube. Continuously rotating rollers rotate on the flexible tube, squeezing it between the rollers and the drum interior, and force the concrete through and out of the tube into the delivery hose.

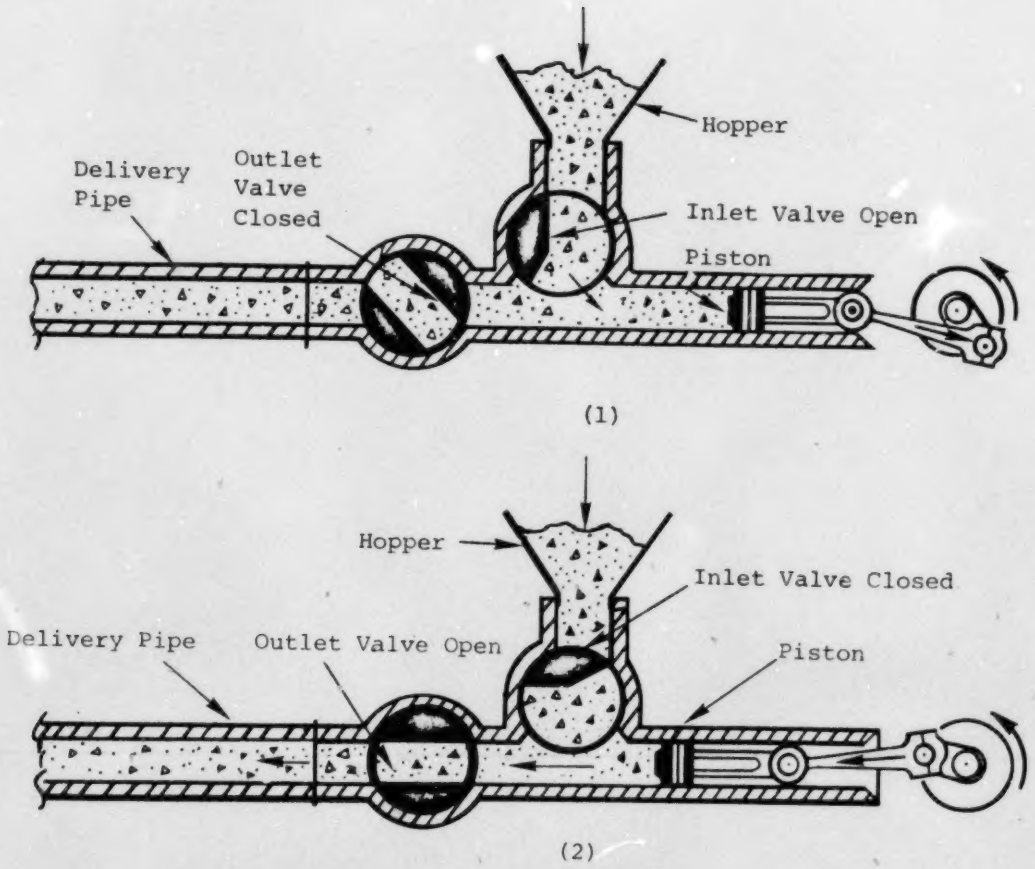



Figure 29-4-4. Concrete Pump, Piston Type

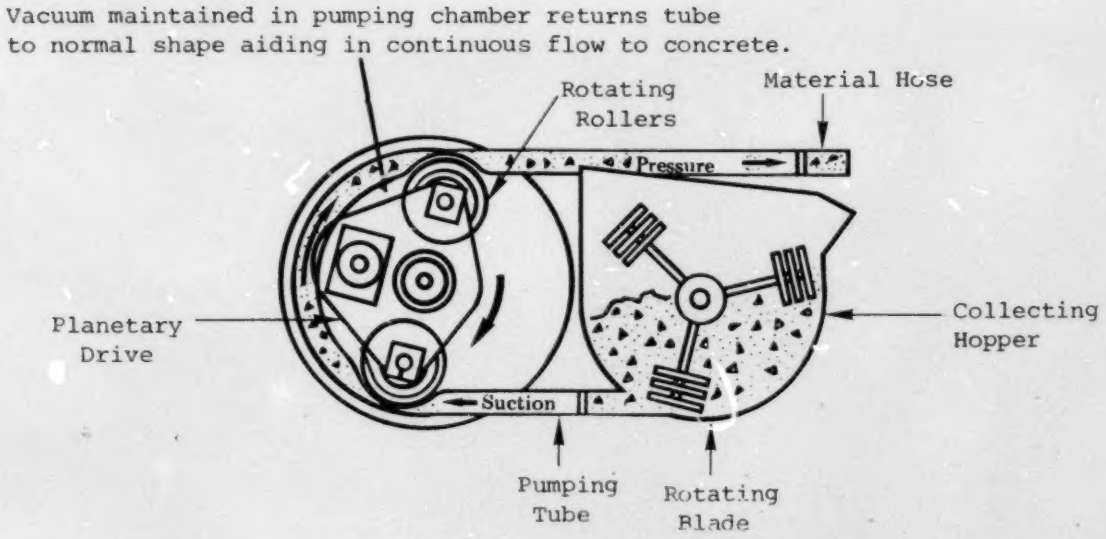



Figure 29-4-5. Concrete Pump, Squeeze Pressure Type

In placing concrete in narrow forms, the concrete should not be allowed to drop unrestrained and strike the form faces or reinforcing bars. Separation of aggregates will occur, resulting in honeycomb at the bottom. When discharging from a chute, buggy, bucket or wheelbarrow, a hopper feeding into a flexible drop chute should be used to contain the concrete as shown in Figure 26-4-6.

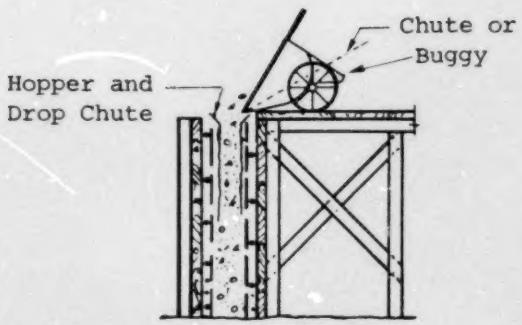



Figure 29-4-6. Placing Concrete in Narrow Forms

In placing concrete in slabs from buggies or wheelbarrows, the concrete should be dumped into the face of the concrete in place, as shown in Figure 29-5-7.

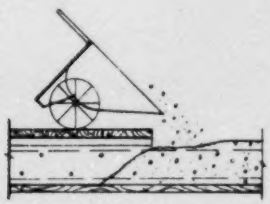


Figure 29-4-7. Slab Concrete Placement

Concrete placed on a sloping surface, discharged from a chute should be restricted with a baffle at the lower end of the chute and allowed to drop a minimum distance into the concrete in place, as shown in Figure 29-4-8. As the placed concrete moves up the slope, the chute is moved upward to allow discharge into the face of the concrete in place.

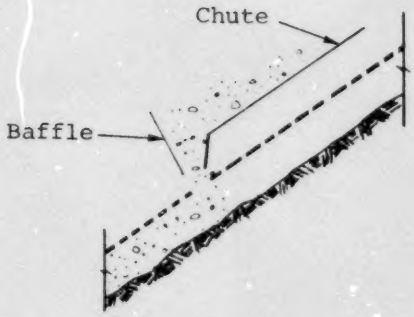



Figure 29-4-8. Concrete Placed on Slope From Chute

When placing concrete by pumping in a deep or curved wall form, the discharge pipe or hose must extend to the bottom of the form and be moved upward as the form fills, as shown in Figure 29-4-9. Allowing the concrete to free-fall from the top of the form will result in segregation.

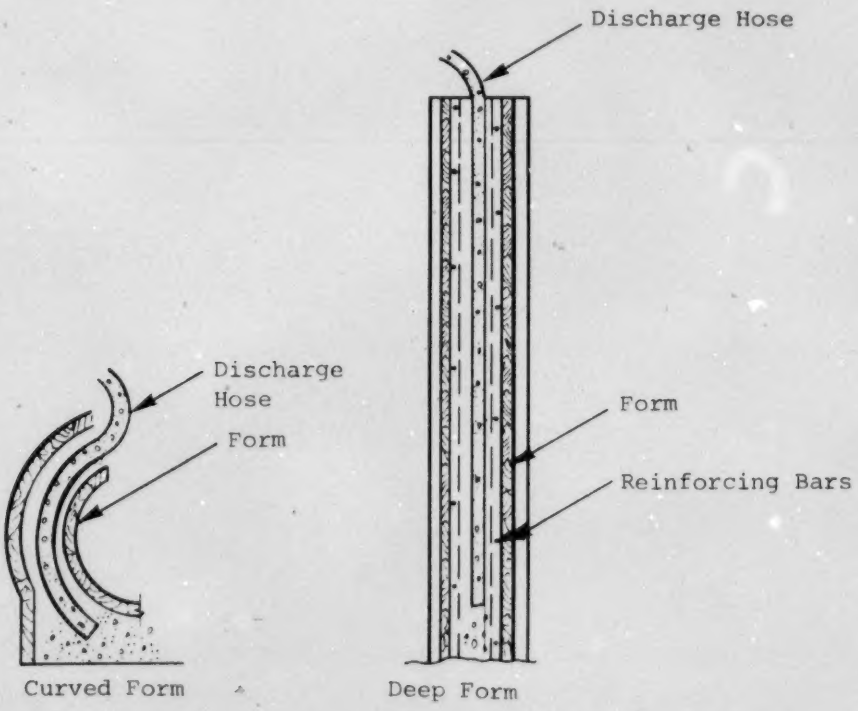



Figure 29-4-9. Placing Pumped Concrete in Curved or Deep Forms

When concrete is placed directly into forms from a crane handled bucket, a flexible drop chute is generally used, attached to the collector cone. The type illustrated in Figure 29-4-10 has a chute which collapses flat when concrete is dropping, allowing it to be used with any size aggregate.

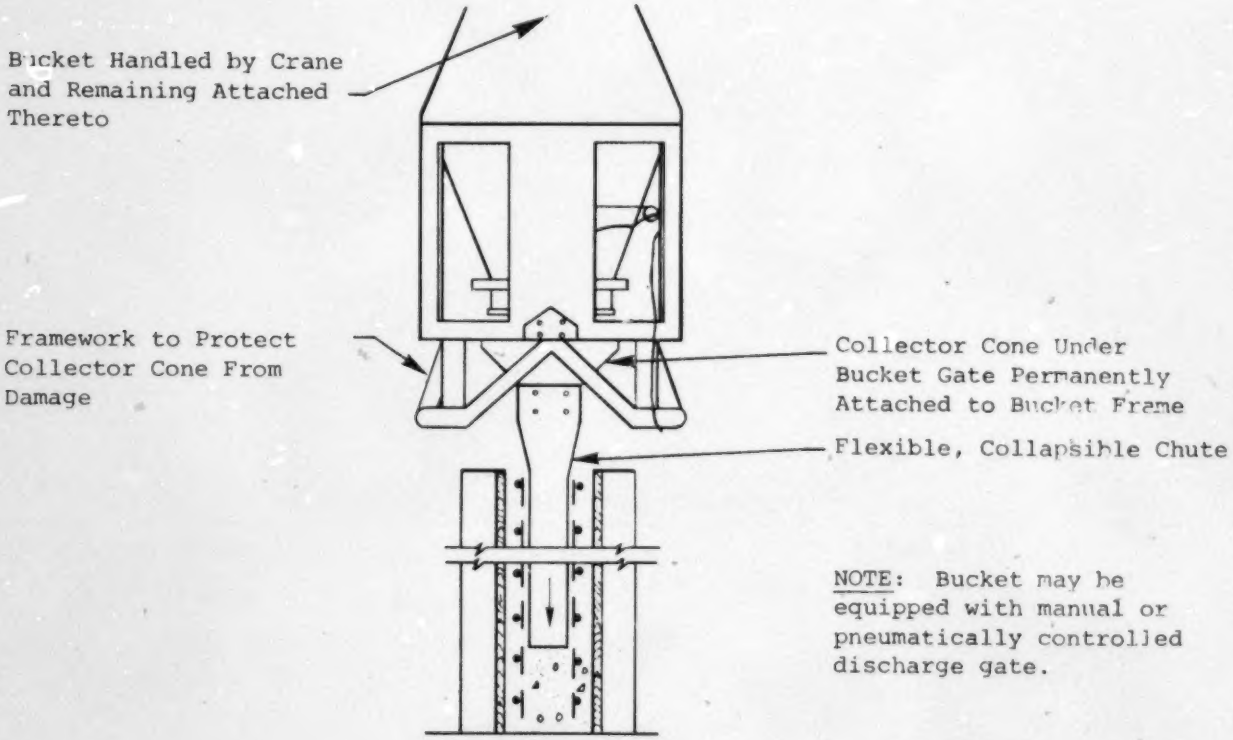

Bucket Handled by Crane and Remaining Attached Thereto
Framework to Protect Collector Cone From Damage
Collector Cone Under Bucket Gate Permanently Attached to Bucket Frame
Flexible, Collapsible Chute
NOTE: Bucket may be equipped with manual or pneumatically controlled discharge gate.

Figure 29-4-10. Concrete Placement From Crane-Handled Bucket

Tremie placement is a method used to place concrete underwater, and consists of feeding the plastic concrete from above the water surface through a vertical pipe by gravity flow under the surface of fresh concrete previously placed. The concrete flows outward from the bottom of the

pipe, pushing the surface of the concrete outward and upward. As long as the flow of concrete is smooth and the surface adjacent to the water is not agitated, the surrounding water is displaced by the denser concrete, and high quality concrete will result. Concrete placed by this method is used primarily for cofferdam seals, and for underwater structural sections such as bridge piers and tunnel construction. Curing conditions in the underwater environment are excellent, and the resulting shrinkage is very low.

Consolidation, also called compaction, is the process of removing entrapped air (air voids) from fresh concrete in the form. Freshly mixed and placed concrete is usually honey-combed with entrapped air, which if allowed to harden in that condition, will produce concrete that is weak, porous, and poorly bonded to reinforcing steel.

The amount of consolidation that is required depends on the workability of the mixture, or the ease with which it can be handled and consolidated. The workability is controlled by the consistency of the concrete, or its ability to flow.

The consistency of the concrete, or its wetness, is normally measured by the slump test. The slump test provides a check on the water-cement ratio and probable strength of the mixture. In making the test, a sample of concrete is placed in an open-ended, sheet metal mold shaped like the frustrum of a cone, resting on a flat surface. It is 12 in. high and has a top diameter of 4 in., and a bottom diameter of 8 in. The mold is filled in a certain manner with the concrete, the top surface struck off even with the top of the mold, and the mold lifted vertically and removed. The distance which the top surface of the molded concrete drops is called the slump. A stiff mixture will have a small slump, and a fluid mixture a large slump.

The values of slump for the entire range of concrete consistencies used in construction are as follows:

| Concrete Consistency Description | Slump, Inches |
|---|---|
| Very Stiff | 0 |
| Stiff | 0 to 1 |
| Stiff Plastic | 1 to 2 |
| Plastic | 3 to 4 |
| Flowing | 5 to 7 |

Consolidation of freshly placed concrete may be accomplished manually or mechanically. Plastic mixtures may be consolidated manually by rodding, e.g., thrusting a tamping rod or other suitable tool into the concrete. A form of rodding called spading is sometimes used to improve formed surfaces. Spading consists of inserting and withdrawing a flat, spade-like tool adjacent to the form.

The most widely used consolidation method is the mechanical technique of vibration. Vibration may be either of the internal or external type, and is especially adapted to the stiffer consistencies associated with high quality concrete. Vibration consists of subjecting fresh concrete to rapid vibratory impulses which liquify the mortar and reduce the internal friction between the aggregate particles. While in this condition, the concrete settles under the action of gravity, and entrapped air rises to the surface, eliminating voids. The liquified mortar mixture tends to flow laterally against the form and around the reinforcing steel.

External vibrators, such as form vibrators and surface vibrators, are seldom used in plant construction work. Internal vibrators, often called "spud" or "poker" vibrators, are used predominantly. This type of vibrator has a vibrating casing or head, is immersed in and acts directly against the concrete, with the vibratory impulses emanating at right angles to the head. Internal vibrators are commonly used having either electrical, pneumatic, or mechanical (flexible shaft) drives.

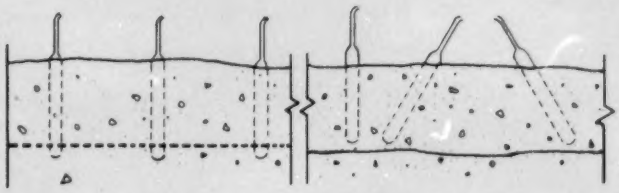
Concrete is normally deposited at close intervals, as level as possible, in layers of 12 to 18 in. The vibrator should not be used for moving the concrete laterally, since segregation might be produced. The vibrator is inserted vertically into the concrete at uniform spacing over the entire area of the placement. The area visibly affected by the vibrator should overlap the adjacent just-vibrated area by a few inches. The vibrator should be inserted rapidly to the bottom of the layer, and at least 6 in. into the preceding layer if there is such. It is then held stationary until the consolidation is considered adequate, and then withdrawn slowly. Normally, the concrete will move back into the space vacated by the vibrator.

The determination of adequate consolidation is based mainly on the surface appearance of each layer of concrete. The principal indicators of well consolidated concrete are:

1. Embedment of large aggregate
2. General leveling of the batch
3. Blending of the batch perimeter together with concrete previously placed
4. Thin film of glistening mortar on the surface
5. Cement paste showing at the junction of the concrete and the form

6. General cessation in escape of large air bubbles at the surface

Figure 29-4-11 illustrates the correct and incorrect methods of consolidation with vibrators.



| Correct | Incorrect |
|---|---|
| Vertical Penetration of Vibrator a Few Inches into Previous Lift (Which Should Not Yet be Rigid) At Systematic Regular Intervals Found to Give Adequate Consolidation. | Haphazard Random Penetration of the Vibrator at All Angles and Spacings Without Sufficient Depth to Assure Monolithic Combination of the Two Layers. |

Figure 29-4-11. Vibrator Consolidation Methods

Undervibration can occur when consolidation is rushed or inadequate equipment is used. Typical imperfections resulting from ineffective vibration are honeycomb, excessive entrapped air voids, sand streaks, stained "pour" line, and lack of bond to reinforcing steel.

Overvibration occurs less commonly, and is usually due to carelessness. Normal weight concretes which are well proportioned and have the recommended slump are not readily susceptible to overvibration. If it does occur, the following deficiencies may result: settlement of coarse aggregate, loss of most of the entrained air in air-entrained concrete, and sand streaks in architectural-type concrete.

## GROUT PRODUCTION AND PLACEMENT

Grout is usually known as a thin, fluid mortar used for filling spaces, such as cracks in concrete foundations, and in the post-tensioned tendon tubes which are used in some containment structures. The term "grouting" usually means "pressure grouting". Pressure grouting consists of forcing the fluid mortar into such locations as those mentioned above with the use of pumping equipment. Grouting operations are generally sequenced to avoid compressing air in pockets or between adjacent grouting holes; in some locations, separate air vents are required. During pressure grouting operations, pressures and methods are generally monitored continuously to preclude disruption or undue movement of parts of the structure.

The material used for pressure grouting consists of a water-cement mixture, which is usually mixed with violent agitation, and is used within 1-2 hours after the cement is wetted. When used for filling voids larger than cracks of about 1/8" wide, fine sand is added to the mixture.

The filling of voids under machinery base plates, column base plates, and around anchor bolts in concrete is also known as grouting. The mixture used for this purpose is known as dry mortar or dry-pack, and usually consists of one part cement to three parts of well-graded fine sand (by weight), with only enough water added to dampen the mixture. When properly mixed, a mass of mortar squeezed in the hand will retain its shape. In mixing the materials, the cement and sand are thoroughly mixed dry, followed by the addition of water.

In preparing an area for dry-pack grout, the base concrete is roughened or chipped, all dust and debris removed, and the surface saturated with water for several days. Just prior to the packing operation, all excess water is removed and a thin layer of cement paste is scrubbed onto the base surfaces as a binding agent.

Packing under the base plate or other item is then done by backing up one side of the open space and ramming the grout in from the other side with paddles of suitable size, shape and length. When the space between the plate and the base has been filled, the back-up block should be removed and the face of the grout rammed from the opposite side. The exposed grout surfaces are then finished by striking off the excess and smoothing with a trowel.

Another common method for filling under base plates and around anchor bolts is the use of flowable expansive grout or nonshrink grout. With these materials, grout is flowed underneath the base plate in a confined space in a manner to completely fill the space without entrapped air pockets. Expansive grouts expand to offset shrinkage during curing, and nonshrink grouts are compounded to cure without shrinkage. Either of these types of grouts are available as field-mixed materials, or as proprietary premixed materials to which water only is added in the field.

## CONSTRUCTION JOINTS

It is usually impossible to pour a large concrete structure in one single, monolithic pour, and joints referred to as construction joints should be used at any location where the concreting is interrupted long enough at any time for the placed concrete to harden. Construction joints are

placed vertically in slabs at predetermined areas of low stress, or at locations where concreting operations are conducted for the day, and are placed horizontally in walls at the top of each list. Figure 29-4-12 illustrates these types of construction joints.

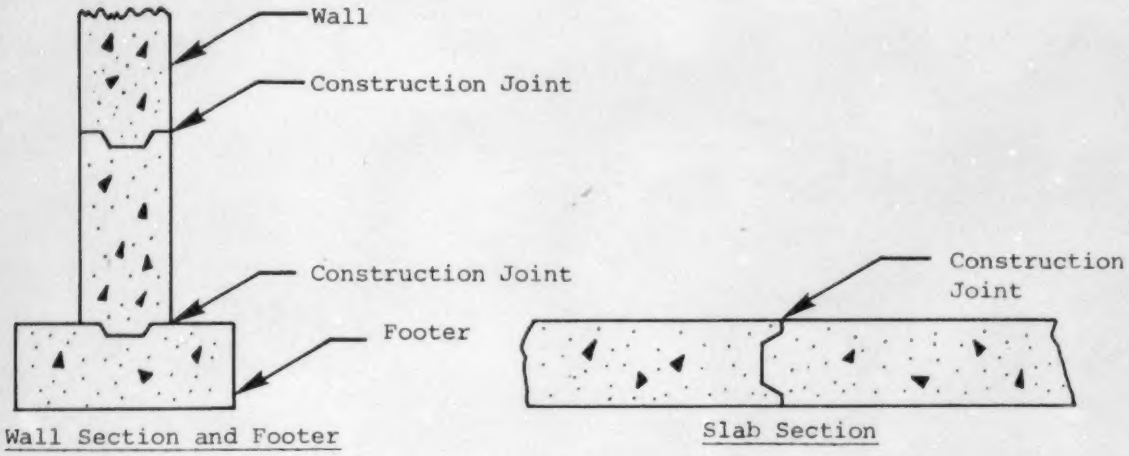



Figure 29-4-12. Typical Construction Joints

Specifications may require the roughening of surfaces or the insertion of dowel bars at construction joints. If only a few hours have lapsed between lifts, roughening or cleaning of the surface may not be necessary. When cleaning is necessary, wire brooming or air-water jets are adequate for use on "green" concrete (concrete usually less than 24 hours old); on older concrete, however, wet sand blasting may be required to remove surface film and contaminations.

Massive, thick concrete mats, such as those found in the foundations of nuclear power plant containment structures, are placed in several vertical lifts. Such structures are usually required to have good bond and integrity between layers, and to achieve that, the horizontal surfaces must

be cleaned to remove any laitance and to expose the coarse aggregate surfaces. (Laitance is an accumulation of fine particles at the surface due to an excess of mixing water.) Such cleaning is usually done on the concrete in the "green" state with air-water jets, and is known as green-cutting. Following this cleaning process, the surface should be kept damp by flushing with water until the new concrete is placed or until the specified time of curing has been fulfilled.

## CONCRETE FINISHING AND CLEANUP

The surface of finished concrete is that part which is subjected to the most severe weather conditions of wetting and drying, freezing and thawing, and wear. The physical condition of the surface, then, is as important as its appearance.

Uniformed surfaces such as those of slabs and pavings, must be worked as little as possible during early finishing operations. The fresh concrete is rough leveled, and spread evenly ahead of the strike off screen. Any water brought to the surface by the float used in rough finishing should be allowed to evaporate before the surface is again floated or troweled. If the amount of water or laitance is excessive, it should be scraped off before the surface is floated again. To secure a smooth, durable surface, final troweling should be delayed as long as possible. Usually the proper time is the time at which the surface can no longer be dented with the finger. If the surface is troweled too soon, a layer scum or laitance is formed on the surface; if troweling is done too late, the partly hardened concrete either is crumbled by the trowel or it is too hard to be troweled effectively.

During final troweling, heavy pressure should be exerted on the trowel to compact the cement paste and form a dense, hard surface. Concrete at edges at joints should generally be edged with an edging trowel and surplus mortar cleared away.

The quality of formed surfaces and finishing work required depends on factors such as the uniformity and consistency of the concrete mix, water content, air content, method of placement, and adequate co. solidation or vibration. Usually the concrete has acquired a considerable degree of hardness by the time the forms are removed. The finish that is required may range from simply "knocking the fins off" and repairing imperfections, to one of several types of decorative finishes.

Areas with defects such as honeycomb should be repaired at once, as hardening continues with time. Such areas should be excavated or cut out to a depth at which good concrete is exposed, and filled with concrete matching that of the structure. Rough areas and high spots should be rubbed or ground down to the proper plane and acceptable degree of smoothness. Holes left by tie rods should be packed with stiff mortar and smoothed out to belnd with the surface. A common surface treatment is to "sack rub" the surface. A creamy slurry of cement, sand and water is rubbed onto the surface with clean burlap bags or sponge-rubber floats so as to fill all surface pits and air bubble holes. Surplus material is removed by rubbing a second application of a dry mix of the same proportions and materials onto the surface, while the first application is still plastic. This method leaves material only in the depressions and none visible on the surface. Formed surfaces finished in this manner will be sealed to the weather, and exhibit greater durability under freezing and thawing conditions.

## RECORDS

Accurate record-keeping is a large and important task in the construction of a nuclear power plant and for many other large construction projects. Records are used to provide evidence that: (1) acceptable materials were used, (2) required inspections were performed, (3) correct materials were installed in the proper place, (4) materials, such as concrete, were properly mixed or prepared, and (5) materials were properly installed, in accordance with the applicable procedures. Records are also used to assist the construction managers and supervisors in controlling and scheduling work in proper sequence with optimum usage of manpower.

The records generated by construction supervisors or the job engineer may include:

- general construction progress reports
- quantities of work performed
- work/manpower scheduling
- materials received and on hand
- extra work performed
- acceptance of parts of structures completed

In the batching and placement of concrete, records are extremely important. Many of the records produced relative to concreting operations are prepared by inspectors. These records may include:

- component materials acceptance
- inspection of concrete batching, placement and curing
- materials testing

Before concrete is batched and placed, many checks have to be made to verify that the area is ready to accept the concrete. Some projects use a "Concrete Pre-Placement

Check-Out Record" form, such as the one shown in Figure 29-4-13, to document this verification. In this case, the Job Engineer would complete the information on the upper part of the form, and the appropriate Craft Supervisor and Field Engineer check and sign-off each check-out item as they are completed. When all items have been checked, the Quality Control Inspector signs the form, releasing the area for concrete placement.

A Quality Control Inspector usually performs an independent check of the area before concrete placement. A typical "Inspector's Concrete Pre-Placement Checkout Sheet" is shown in Figure 29-4-14, which lists most of the items for checking. Such forms are normally retained along with the other project Quality Control records.

Actual concrete placement is usually witnessed and inspected by a Quality Control Inspector. Figure 29-4-15 illustrates a typical "Report of Concrete Placement" form which records the identification and location of the pour area, acceptability of forms and reinforcement, equipment used, and method of delivery of concrete to the forms and consolidation.

Following the placement in the forms and initial set of the concrete, the curing process begins. Figure 29-4-16 shows a typical "Daily Concrete Curing Record" form, which is prepared by the Job Engineer and turned over the Quality Control Inspector. The Quality Inspector then performs a daily inspection, for a specified time period, and records the concrete temperature and verifies that proper cover or protection, and designated curing method is being used.

Similar records are maintained for batch plant operations, concrete delivery tickets for each load transported, component materials testing, concrete cylinder testing, grouting operations and sample tests, reinforcing steel bar test, and reinforcing steel bar splice weld tests.

| | | |
|---|---|---|
| Pour Area: | Type Pour: | Date: _____ |
| Location: | | Superior Engineering, Inc.<br>Skunk Holler Nuclear Station |
| Strength Required: | | Curing Req'd.: Durability ☐<br>Load Bearing ☐ |
| Quantity Required: | | |
| Mix Code No: | Cement: | Class Struct.: Very Thin ☐<br>Thin ☐<br>Mod. Mass. ☐<br>Massive ☐ |
| Finish Required: | Grout: | |
| Date & Time Scheduled to Pour: | | |

| Checkout Item | Craft Supervisor | Field Engineer | REMARKS<br>Minor Items to Complete Prior to Placement (if none, print "none") |
|---|---|---|---|
| 1. Surface Preparation | | | |
| 2. Formwork | | | |
| 3. Reinforcing Steel | | | |
| 4. Sleeves and Block-Outs | | | |
| 5. Embedded Misc. Iron | | | |
| 6. Anchor Bolts | | | |
| 7. Piping Embeddments | | | |
| 8. Electrical Embeddments | | | |
| 9. Line and Grade | | | |
| 10. Quality Con. Rel. | | | |
| Item 10 must be signed and copies given to Concrete Placement Supervisor and Job Engineer prior to issuing initial order to batch concrete. | | | |

Distribution:

Project Superintendent
QC Supervisor
Concrete Placement Supervisor
Test Lab

_____
Job Engineer

Figure 29-4-13. Concrete Pre-Placement Checkout Record

Superior Engineering, Inc. | Skunk Holler Nuclear Station

Pour Area: _____ | Location: _____

---

A. Concrete Schedules, Pour Sheets, Plans:
- __ 1. Completeness
- __ 2. Craft Cert. of Readiness
- __ 3. Updated & Available of Plans
- __

B. Subgrade:
- __ 1. Compaction
- __ 2. Vapor Barriers Installed
- __ 3. Perimeter Insulation
- __ 4. Condition of Materials Used

C. Construction Joints:
- __ 1. Laitance Removed
- __ 2. Proper Location
- __ 3. Expansion Joint Materials
- __ 4. Contraction Joints and Filler
- __ 5. Spalling

D. Forms:
- __ 1. Form Surface
- __ 2. Panel Joints
- __ 3. Bracing
- __ 4. Tie Spacing
- __ 5. Make-Up of Ties
- __ 6. Waler Spacing & Size
- __ 7. Spreaders
- __ 8. Grout Leaks
- __ 9. Form Coating
- __ 10. Chambers Where Necessary
- __ 11. Grade Strip Properly Installed
- __ 12. Pumb Bob Lines Installed
- __ 13. Horizontal Form Liner Installed
- __ 14. Horizontal & Vertical Alignment
- __ 15. Installation of Keyways on Previous Cone
- __ 16. Proper Metal Lath Bulkhead Clearance

E. Blockouts:
- __ 1. Proper Size
- __ 2. Proper Location
- __ 3. Internal Bracing & Shoring
- __ 4. Vibrator Holes Top & Bottom
- __ 5. Grout Tight

F. Water Stops:
- __ 1. Proper Location
- __ 2. Joint Welds
- __ 3. Supported for Conc. Placement
- __ 4. Water Stop Wedged into Keyways
- __ 5. Cleanliness

G. Embedded Items:
- 1. Anchor Bolts, Inserts, Pipe Sleeves, Pipe Conduits, Flashings, etc.
  - __ a. Proper Projection
  - __ b. Proper Location
  - __ c. All Threads Wrapped
  - __ d. Secured for Conc. Placement
- 2. Misc. Steel
  - __ a. Proper Location
  - __ b. Secured or Supported
  - __ c. Check Drawings for Type & Number

H. Reinforcing Steel:
- __ 1. Proper Spacing
- __ 2. Number & Size of Bars
- __ 3. Length of Laps
- __ 4. Length of Dowels & Alignment
- __ 5. Cadwelds
- __ 6. Ties
- __ 7. Form Clearance
- __ 8. Supports

I. Final Clean-Up:
- __ 1. Check Forms for Displacement
- __ 2. Cleanliness of All Surfaces
- __ 3. Proper Scaffolding
- __ 4. Concrete Chute Arrangement
- __ 5. Proper Type & Length of Tremies

J. Miscellaneous:
- __ 1.
- __ 2.
- __ 3.
- __ 4.

K. Additional Remarks:

L. (Reactor Building Pours Only)
- __ 1. Have Tendons Been Tested and Approved?

Ready for Placement:

_____ _____
Inspector Date

Figure 29-4-14 Inspector's Concrete Pre-Placement Checkout Sheet

_____ Skunk Holler Nuclear Station

Pour Area: _____ Date: _____
Location: _____
Weather Conditions: _____

| Forms | Initial When Accepted | Reinforcement | Initial When Accepted |
|---|---|---|---|
| Properly Coated | __ | Proper Clearance | __ |
| Free From Holes | __ | Proper Support | __ |
| Seams Tight | __ | Clean | __ |
| Clean | __ | Tie Rods Type _____ | __ |
| Proper Shoring | __ | Spacing _____ | __ |

Equipment

No. and Size of Vibrators _____
Placement Equipment _____
Tremie Pipes and Number _____ Size _____ Location _____

Placement

Consolidation _____
Grouted _____ Time _____
Concrete: Lift Depth _____ Direction of Pour _____

Remarks:

_____ _____
Quality Control Inspector Date

Figure 29-4-15 Report of Concrete Placement

Superior Engineering, Inc. — Skunk Holler Nuclear Station

Pour Area: _____ Date: _____
Location: _____

Inspect Concrete Curing for Compliance with: Summer Curing Method _____
Winter Curing Method _____

Prepared By: _____ Date: _____
Job Engineer

---

Summer Curing Method

- ☐ Covered with Wet Burlap
- ☐ Sealed with Curing Compound

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| DATE | | | | | | | | |
| CONCRETE TEMP. (°F) | | | | | | | | |
| MINIMUM TEMP. REQUIREMENT (°F) | | | | | | | | |
| INSPECTOR'S INITIALS | | | | | | | | |

Winter Curing Method

- ☐ Insulated Forms
- ☐ Plywood Forms
- ☐ Wet Burlap
- ☐ Polyethylene, Straw & Tarps
- ☐ Heated & Vented
- ☐ Other _____

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| DATE | | | | | | | | |
| CONCRETE TEMP. (°F) | | | | | | | | |
| TEMP. REQUIREMENT (°F) | | | | | | | | |
| INSPECTOR'S INITIALS | | | | | | | | |

REMARKS:

Quality Control Inspector: _____

Figure 29-4-16 Daily Concrete Curing Record

Weekly and monthly summary reports are usually prepared from daily reports, summarizing work progress and average quality of the work. Inspectors sometimes are required to maintain diaries covering work progress, delays, unsatisfactory conditions, and special instructions received. For all records, the primary objective is accuracy.

## EXERCISES

1. Complete the following table to identify codes and standards used for concreting operations and the responsible technical society.

| Applicable to | Society | Number and Name of Code Standard |
|---|---|---|
| Slump Test | | |
| Portland Cement | | |
| Hot Weather Concreting | | |
| Concrete Framework | | |
| Testing Ready Mix | | |
| Reinforcing Bars | | |

2. Describe the significance of normal weight, light weight, and heavy weight concretes.

3. Describe the potential deleterious effects on concreting operations of:
   a. hot weather
   b. cold weather

4. What is meant by separation and how is it avoided?

5. What is meant by consolidation and how is it avoided?

6. Complete the following table for slump tests:

| Concrete Consistency | Acceptable Slump Range |
|---|---|

7. Describe how honey combining can occur in cured concrete.

8. Complete the following table to identify the purpose of records.

| Record | Purpose |
|---|---|
| Preplacement Checkout | |
| Inspection Preplacement Checkout | |
| Report of Concrete Placement | |
| Daily Concrete Curing Record | |

## MATERIALS

The following materials are required to support this module:

1. Premixed concrete
2. Concrete forms
3. Water supply with hoses
4. Mixing trough or machine
5. Steel Rods
6. Trowels

## PROCEDURES

1. Tour a construction site and observe concreting operations. Take notes on the following and discuss them in class:
   a. Method of Transporting
   b. Method of Mixing
   c. Method of Placement
   d. Method of Consolidation
   e. Tests Conducted
   f. Method of Finishing
   g. Types of Records
2. Experiment with concreting operations by mixing and placing concrete in three distinctly different manners as follows. Take notes on visual appearance of each batch and the intervals of prior to placement, after placement, after finishing, and after removal of forms. Compare notes in class.
   a. Batch #1
      1) Mix per manufacturer's instructions

2) Wet form
3) Place concrete in form by vertical pour
4) Compact concrete by ramming steel rod vertically into form
5) After hardening to finger touch, finish with trowel
6) After 48 hours remove form

b. Batch #2
1) Mix per manufacturer's instructions except add 50% more water than recommended.
2) Wet form
3) Place concrete in form by vertical pour
4) Immediately finish with trowel
5) After 48 hours remove form

c. Batch #3
1) Mix per manufacturer's instructions
2) Do not wet form
3) Place concrete by pour at one end
4) If necessary, concrete with steel rod or other hand tool in horizontal direction to fill form. Use minimum agitation.
5) After 48 hours, remove form

## DATA TABLE

None

# REFERENCE MATERIALS

ACI, Manual of Concrete Practice, American Concrete Institute, Detroit, MI

PI, Materials, Design and Control of Quality Concrete, Protex Industries Inc., Denver, Colorado

NRMCA, Control of Quality of Ready-Mixed Concrete, National Ready-Mixed Concrete Assoc., Silver Spring, MD

CRSI, Placing Reinforcing Bars, Concrete Reinforcing Steel Institute, Chicago, Illinois

Recommended Guide Specifications for Batching Equipment and Control Systems in Concrete Batch Plants, Concrete Plant Manufacturers Bureau, Silver Spring, MD

# TEST

1. Name two technical societies who publish codes and standards applicable to concreting operations and list one standard published by each of the named societies.

2. Describe the concrete represented by the following terms:
   a. Normal weight:

   b. Lightweight:

   c. Heavyweight:

3. What is the purpose of the slump test?

4. List three (3) materials used as aggregates or filler materials in concrete for radiation absorption:
   _____, _____, _____.

5. Mark the following statements true or false:
   a. The optimum temperature for placing mixed concrete is about $90^{\circ}F$.

      _____

   b. The temperature of mixing water has little effect on the temperature of the mixed concrete.

      _____

   c. Accelerated set and high rate of evaporation of mixing water are characteristics of cold weather concreting operations.

      _____

   d. Concrete must be protected from freezing until required strength is attained.

      _____

e. Ice may be used in the concrete mix during hot weather operations.

_____

f. Accelerating admixtures are frequently used to prevent freezing.

_____

6. Why is it important to control the measurement and addition of water in batching concrete?
7. Why must mixers be operated at the proper speed?
8. Describe how concreting operations can be carried out in cold weather.
9. Describe the conditions which warrant use of ice in the batching operation.
10. Are massive concrete sections more susceptible to freezing than thin sections?
11. Complete the following statements:
    a. The primary consideration in handling and placing concrete is to avoid _____.
    b. Concrete conveyors are designed to operate fast with minimum vibration to minimize _____.
    c. Concrete should be discharged into the _____ _____ of handling equipment and forms.
    d. _____ are used in transferring concrete from one conveyor belt to another.
    e. The basic operating components of a piston type concrete pump are the _____, _____, and _____.
    f. Concrete is forced through the squeeze type pump by the action of the _____.
    g. Tremie concrete is normally used for _____ _____ applications.
    h. Honeycomb in concrete may result from _____ _____ or _____.

12. Mark the following statements true or false:

a. Loss of entrained air and settlement of coarse aggregate are indicators of overvibration.

_____

b. Vibrators are more useful in spreading concrete than in mixing adjacent layers.

_____

c. Mechanical consolidation of concrete is also known as rodding.

_____

d. Stiff concrete exhibits a very low slump.

_____

e. Flexible discharge hoses or drop chutes should be lowered to the bottom of deep forms to avoid segregation resulting from free-fall.

_____

13. A large compressor base plate elevated 2" above base concrete is to be set in place and grouted with dry-pack.

a. What base surface preparations are recommended before setting the base plate in position?

b. What base surface treatment is recommended prior to grout installation?

c. How should grout be installed?

d. How should the exposed grout surfaces be finished?

14. Mark the following statements true or false:

a. Premature final troweling during finishing operations may produce a layer of laitance on the concrete surface.

_____

b. On unformed surfaces, light pressure should be maintained during final troweling to produce a smooth surface.

_____

c. Honeycomb areas appearing on formed surfaces are inconsequential, and may be covered up with back fill.

_____

d. A mixture of cement and water is frequently used as a "sack-rub" finish.

_____

e. Concrete durability is enhanced by effective surface finishing and sealing.

_____

15. Name two record forms used for concreting operations and state the purpose of each.